The Midwest U.S. Corn-Soybean Rotation: Is it Sustainable?

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Overview

• The Rotation Effect
  ✓ What is it?
  ✓ Research retrospective

• Sustainability of Current Midwest Corn Belt Cropping Systems
  ✓ Challenges
  ✓ Wisconsin Rotation Trials
  ✓ “The Lancaster Rotation Experiment”
The Rotation Effect - What is it?

• Crop Rotation
  ✓ Universal management practice
  ✓ Proven management decision that increases crop yields
  ✓ Currently, increased economic benefit for monoculture

• Rotation Effect
  ✓ The effect of all conditions, other than N, supplied by legumes in a rotation (Baldock et al., 1981)
  ✓ Other non-legume crops can provide benefits as well (Robinson, 1966; Langer and Randall, 1981; Crookston et al., 1988)
  ✓ Additional benefits of rotating crops
    ❑ All production inputs can be optimized
    ❑ Typical problems associated with monoculture are not apparent.

• Mechanism for effect is unknown
Current Challenges to the Midwest Corn-Soybean Cropping System

- **Row crop** = soil erosion potential
- **Inputs affecting water quality**
  - **Pro**: increase in N fertility
  - **Con**: decrease in organic matter
- **Energy / Natural gas for:**
  - Ammonia production
  - Fall drying
- **Corn insects**
  - Northern corn rootworm: extended diapause
  - Western corn rootworm: variant
  - Development of resistance to transgenic crops
- **Soybean Diseases**
  - Brown stem rot
  - White mold
  - Sudden death syndrome
  - Soybean rust “threat”
- **Soybean insects**
  - Soybean aphid
  - Bean leaf beetle
- **Soybean cyst nematode**
- **Corn diseases**
  - Gray leaf spot
  - Mycotoxins
  - Anthracnose
- **Weeds**
  - Development of resistance to Round-up

[Further details and images related to soil erosion, fertilizer use, energy sources, and pest management.]
# The Wisconsin Rotation Trials

<table>
<thead>
<tr>
<th>Corn-Soybean-Oat-Alfalfa-Wheat</th>
<th>Corn-Soybean-Wheat</th>
<th>BioChar</th>
<th>Corn-Alfalfa</th>
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<tbody>
<tr>
<td><strong>since 1983</strong></td>
<td><strong>since 2001</strong></td>
<td><strong>since 2009</strong></td>
<td><strong>ARL and MAR since 2010</strong></td>
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<td>CC</td>
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<td>SS</td>
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<td>CS</td>
<td>SS</td>
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<tr>
<td>CSCOA</td>
<td>CCCCSSSSSS</td>
<td>Tillage=6</td>
<td>CCAA</td>
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<td>CCCOA</td>
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<td>Starter</td>
<td>CCAA</td>
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<tr>
<td>CCOAA</td>
<td></td>
<td>Planting date</td>
<td>CCAA biomass</td>
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<tr>
<td>COAAA:1966-1976</td>
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<td>CCAAA:1977-1986</td>
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<td>AA:1977-2004</td>
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<td>CS:1987-</td>
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<td>CA:1987-2004</td>
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<td>CSW:2005-</td>
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<td>Tillage=2</td>
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<td>N rate</td>
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<td>Cultivar</td>
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<td>Row spacing</td>
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<td>Seed insecticide</td>
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<td>N timing</td>
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<td>Systems Trials</td>
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<td>Weeds 1987-</td>
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<td>WICST 1990-</td>
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<td>GLBRC 2009-</td>
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<tr>
<td>Corn N rate</td>
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<tr>
<td>1966-76: 0, 75, 150, 300</td>
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<td>1977- : 0, 50, 100, 200</td>
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<td>Lauer © 1994-2010</td>
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<tr>
<td><a href="http://corn.agronomy.wisc.edu">http://corn.agronomy.wisc.edu</a></td>
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<td>Photo by Justin Hopf</td>
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</tbody>
</table>
How should we study the rotation effect?
Rotation Experiment Design Considerations

- Methodology worked out by Fischer, Cochran and Yates
- Types (Patterson, 1964)
  - Short-term (few cycles) with or without agronomic treatments sometimes followed by a test crop for all plots.
  - Long-term fixed rotations (many cycles)
    - Kellogg Biological Station Long-Term Ecological Research (LTER) Program (Michigan)
    - Rothamsted
  - Multi-rotation comparing crop sequences with or without treatments. (many researchers)
  - New: System rotations
    - Wisconsin Integrated Cropping Systems Trial (WICST)
- Design principles (Brandt, 1945)
  - Provide for all crop phases in all years
  - Replication
    - Spatial
    - Temporal
  - Randomization
- Other considerations (Cady, 1991)
  - Site selection
  - Plot size and shape
  - Block size
  - Preliminary years – setup
- Recently, computer and data management techniques allow for sophisticated statistical analysis.
Crop Sequence for 2-Crop Rotation Experiment in Lamberton and Waseca, MN and Arlington, WI

C= Corn, S= Soybean

<table>
<thead>
<tr>
<th>Sequence</th>
<th>“Setup years”</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4</td>
<td>5 6 7 8 9 10</td>
</tr>
<tr>
<td>1</td>
<td>C C C C</td>
<td>C C C C C C</td>
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<tr>
<td>2</td>
<td>S S S S</td>
<td>S S S S S S</td>
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</tbody>
</table>
The rotation effect lasts two years increasing corn grain yield 10 to 19% for 1C and 0 to 7% for 2C...

Corn Yield Response Following Five Years of Soybean

Control treatments averaged across tillage treatments at Arlington, WI.

Source: Lauer

C= Corn, S= Soybean, Number = consecutive year of corn

Visit http://corn.agronomy.wisc.edu for more information.
The rotation effect lasts two years increasing soybean grain yield 10 to 20% for 1S and 8% for 2S ...

Soybean Yield Response Following Five Years of Corn

Control treatments averaged across tillage treatments at Arlington, WI.

Source: Lauer

C= Corn, S= Soybean, Number = consecutive year of soybean
If there is only a one year break in the rotation, then the second corn phase is equivalent to continuous corn ...

Corn Yield Response to Crop Rotation

Grain Yield (bushels/acre)

Control treatments averaged across tillage treatments at Arlington, WI.

Cropping Sequence

C= Corn, S= Soybean, Number = consecutive year of corn

Source: Lauer

Lauer © 1994-2010
http://corn.agronomy.wisc.edu
At least two break years are needed to measure a response in the second corn phase (compared to CC) ...

Corn Yield Response to Crop Rotation

Control treatments at Lancaster, WI.

Source: Stanger and Lauer, 2008

Cropping Sequence
A= Alfalfa, C= Corn, O= Oat, S= Soybean, W=Wheat

10% 16% 12% 7% 5% 18% 8% 16% 10%
CD  AB  BC  D  DE  A  CD  AB  CD  E

Grain Yield (bushels/acre)

Source: Stanger and Lauer, 2008
Adding a third crop does not increase corn grain yield, but does improve soybean grain yield ...

Corn and Soybean Yield Response to Crop Rotation

Cropping Sequence
C= Corn, S= Soybean, W=Wheat

2004-2006: Values averaged across seed fungicide treatments at Arlington, WI.

Source: Lauer

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http://corn.agronomy.wisc.edu

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Management Decision Interactions with Rotation

**Significant**
- Tillage
- N rate
- CR Insecticide
  - CR Variant = NS (need all the time)
- Environment

**Non-significant**
- Plant density
- Row spacing
- Modern hybrids versus old hybrids
  - Modern hybrids can “handle” continuous corn
How can you tell if a cropping system is changing?

Yield

Deteriorating

No change

Improving

Control

Time
Corn yield in Wisconsin and the U.S. since 1866

The yield march continues ...

Source: USDA-NASS
The Lancaster Rotation Experiment
A Long-Term Cropping System Study

• A multiple crop rotation experiment established in 1966

• Objective: To compare the benefits of growing corn continuously and in rotation using commercial nitrogen fertilizer.

• RCB in a split-plot arrangement with two replications.
  ✓ Main-plots = 21 rotations
  ✓ Split-plots = four N levels in corn production year
### History of the Lancaster Rotation Experiment

<table>
<thead>
<tr>
<th>Year of change</th>
<th>Rotations</th>
<th>Corn N rates (lbs N A⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>CC CSCOaA CCOaAA COaAAA</td>
<td>0, 75, 150, &amp; 300</td>
</tr>
<tr>
<td>1977</td>
<td>CC CSCOaA CCCAA CCOaAA CCAA AA</td>
<td>0, 50, 100, &amp; 200</td>
</tr>
<tr>
<td>1987</td>
<td>CC CSCOaA CCCAA CCOaAA CS CA AA</td>
<td>0, 50, 100, &amp; 200</td>
</tr>
<tr>
<td>2005</td>
<td>CC CSCOaA CCCAA CCOaAA CS CSW</td>
<td>0, 50, 100, &amp; 200</td>
</tr>
</tbody>
</table>

- **C**, Corn; **S**, Soybean; **Oa**, Oat with alfalfa seeding; **A**, Alfalfa; **W**, Wheat
- **C**, first phase; **C**, second phase; **C**, third phase
Corn Yields in the Lancaster Rotation Experiment
(Analysis over time: 1970-2004)

Source: Stanger and Lauer, 2008
# Analysis over Time and Space (2-yr and 5-yr Cycles)

<table>
<thead>
<tr>
<th>Cycle</th>
<th>CC</th>
<th>Cycle</th>
<th>CS</th>
<th>Cycle</th>
<th>CSCOaA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>1</td>
<td>C</td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>1</td>
<td>S</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>2</td>
<td>C</td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>C</td>
<td>2</td>
<td>S</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>3</td>
<td>C</td>
<td>S</td>
<td>1</td>
</tr>
</tbody>
</table>
Corn grain yield response to N rate in a continuous corn rotation (over time and space) at Lancaster, WI.

- 0 lb N/A  slope = NS
- 50 lb N/A  slope = NS
- 100 lb N/A  slope = NS
- 200 lb N/A  slope = 0.9 bu/A*yr (P < 0.10)

Source: Stanger and Lauer, 2008
Corn grain yield response to N rate in a CSCOaA rotation (over time and space) at Lancaster, WI.

Source: Stanger and Lauer, 2008
Is Corn Grain Yield Changing? (Is there a slope?)
First Corn Phase in 5-yr Cycles (1970-2004; 7 Cycles)

<table>
<thead>
<tr>
<th>Rotation</th>
<th>N rate (lb N A⁻¹)</th>
<th>bu A⁻¹ yr⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>CC</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>CCCAA</td>
<td>1.2**</td>
<td>1.1**</td>
</tr>
<tr>
<td>CCOaAA</td>
<td>1.3**</td>
<td>1.2**</td>
</tr>
<tr>
<td>CSCOaA</td>
<td>1.2**</td>
<td>1.1**</td>
</tr>
</tbody>
</table>

†, *, **, *** Significant at the 0.10, 0.05, 0.01, and 0.001 levels

Source: Stanger and Lauer, 2008

http://corn.agronomy.wisc.edu
Corn grain yield response to N rate in a CSCOaA rotation (over time and space) at Lancaster, WI.

Source: Stanger and Lauer, 2008

Lauer © 1994-2010
http://corn.agronomy.wisc.edu
Are CC, CSCOaA and CS rotations improving (+) or deteriorating (-) for grain yield? ... YES!

Ultimate decision for farmer is based upon economics.

CS at 50, 100, and 200 lb N/A and CC at 200 lb N/A were the most profitable AND least risky of rotation treatments.

Source: Stanger and Lauer, 2008
Yield Contest Winners - Do Not Use Crop Rotation

- Herman Warsaw, Saybrook, IL
  - 1985: 370 bu/A

- Ken Beaver, Sterling, NE
  - >300 bu/A

- Francis Childs, Manchester, IA
  - World Record = 442 bu/A
  - 30+ years continuous corn
Conclusions

• The rotation effect lasts at most two years increasing grain yield 10 to 19% for 1C and 0 to 7% for 2C.

• Adding a third crop does not improve corn yield, but does improve soybean yield.

• At least two break years are needed to measure a response in the second continuous cropping year.

✓ A one year break using soybean reduces the rotation effect in the second continuous year.

• Tillage does not affect yield the first year following soybean, but improves yield 5% in the second year, and 9% in the third year.

• N fertilization response increases in 2C and 3C of the rotation, so err on the high side of the N application range.

• Modern corn hybrids and management practices have the same rotation response as older hybrids and practices.
The End For Now - Questions?
Thanks for your attention!

Steve Wilkens
Justin Hopf
Zhe Yan
Trenton Stanger
Palle Pedersen
Heather Darby
Jorge Cusicanqui

Kent Kohn
Thierno Diallo
Keith Hudelson
John Gaska
Tim Wood
Mike Bertram
Dwight Mueller
Darwin Frye

Johnny Pendleton
Ed Oplinger
Paul Carter
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Larry Bundy
Greg Roth
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Photo by Justin Hopf